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Description

[Flame and Heat Resistant Oilfield Tools]

BACKGROUND OF INVENTION

[0001] The present invention relates generally to fire resistant well tools and components, and more particularly to a perforating gun assembly protected by a heat resistant and/or flame retardant coating.

[0002] Well operations typically involve the use of tools and tool components that are heat or flame-sensitive or even explosive when exposed to high temperature stresses or fire. For example, one operation that is performed in completing a well using an explosive tool is the creation of perforations in a formation. This is typically done by lowering a perforating gun string containing explosive shaped charges to a desired depth in a wellbore and activating the gun string to fire the shaped charges. The shaped charges when fired create perforating jets that form holes in surrounding casing as well as extend perforations into the surrounding formation.

[0003] The handling of perforating tools (e.g., charge carriers,

loading tubes, detonators) or explosive components (e.g., shaped charges, propellants, actuators) during transportation, assembly, and operation necessarily involves the risk of exposure to heat or flame. Such exposure may damage the tools resulting in faulty operation, or worse ignite the explosive components causing bodily injury and/or severe damage to property.

[0004] A need thus exists for a method and apparatus to protect heat and/or flame-sensitive well tools, and explosive tool components and elements.

Summary of Invention

[0005] In general, according to an embodiment, the present invention provides heat resistant and/or flame retardant oil and gas well tools and explosive tool components.

[0006] For example, embodiments of the present invention include well tools and explosive tool components protected by a heat resistant and/or flame retardant coating.

[0007] In general, according to another embodiment, the present invention provides heat resistant and/or flame retardant containers and packing material for shipping, transporting, packaging, and/or storing oil and gas well tools, explosive tool components, and explosives.

[0008] For example, embodiments of the present invention in-

clude containers and packing material protected by a heat resistant and/or flame retardant coating for storing, shipping, and packaging well tools, explosive tool components, and explosive.

[0009] Other or alternative features will be apparent from the following description, from the drawings, and from the claims.

Brief Description of Drawings

[0010] The manner in which these objectives and other desirable characteristics can be obtained is explained in the following description and attached drawings in which:

[0011] Figure 1 is a profile view of a typical perforating gun being run down a cased wellbore.

[0012] Figure 2A is a cross-sectional view of a non-capsule shaped charge and an embodiment of the protective coating of the present invention.

[0013] Figure 2B is a profile view of a set of capsule charges and an embodiment of the protective coating of the present invention.

[0014] Figure 3A is a profile view of a perforating gun illustrating the assembled shaped charge, loading tube, and hollow carrier and an embodiment of the protective coating of the present invention.

[0015] Figure 3B is a cross-sectional view of the perforating gun depicted in Figure 2A illustrating the shaped charge, loading tube, and hollow carrier and an embodiment of the protective coating of the present invention.

[0016] Figure 4 is a sectional view of an exploding foil initiator and an embodiment of the protective coating of the present invention.

[0017] Figure 5 is a profile view of a detonator assembly illustrating the assembled detonator, initiator, processor, and power supply with an embodiment of the protective coating of the present invention.

[0018] Figure 6 is an isometric view of a container and packing material for holding one or more shaped charges, and an embodiment of the protective coating of the present invention.

[0019] It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

DETAILED DESCRIPTION

[0020] In the following description, numerous details are set forth to provide an understanding of the present inven-

tion. However, it will be understood by those skilled in the art that the present invention may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0021] In the specification and appended claims: the terms "connect", "connection", "connected", "in connection with", and "connecting"are used to mean "in direct connection with"or "in connection with via another element" the term "set"is used to mean "one element"or "more than one element" and the term "downhole tool"is used to mean "an explosive well tool", "an explosive well tool component" and/or "an explosive for use in well operations". As used herein, the terms "up"and "down", "upper"and "lower", "upwardly"and downwardly", "upstream"and "downstream" "above"and "below" and other like terms indicating relative positions above or below a given point or element are used in this description to more clearly described some embodiments of the invention. However, when applied to equipment and methods for use in wells that are deviated or horizontal, such terms may refer to a left to right, right to left, or other relationship as appropriate.

[0022] Generally, a protection system is provided for shielding explosive tools and/or explosive tool components from

exposure to high temperature stresses or fire. More particularly, embodiments of the present invention include oil and gas well tools having explosive components -- such as perforating tools -- having a heat resistant and/or flame retardant coating to prevent detonation during a fire or exposure to heat and flame.

[0023] In embodiments of the present invention, any heat resistant and/or flame retardant coating (also referred to herein as "thermal coating") may be used to protect a well tool or tool component. For example, FX-100®coating by Flame Seal Products, Inc. is a Class A, super-intumescent coating which may be applied to a variety of materials including, but not limited to, metal, plastic, wood, paper, and other porous or non-porous materials. FX-100® coating forms a thick, insulating barrier when exposed to fire. Another example is Albi Clad 800™coating by Albi Manufacturing. Albi Clad 800™ coating is a solvent-based, intumescent mastic fire protective coating capable of resisting weathering and severe environmental stresses and is applicable to many materials including, but not limited to, steel, concrete, and other construction materials. Albi Clad 800™expands from a thin coating into a foam-like substance when exposed to fire. Yet another example is

Corr-Paint™ CP40XX coating by Aremco Products, Inc. Corr-Paint™CP40XX coating is a series of silicone-based, heat resistant coatings formed using a water-dispersable silicone resin. Corr-Paint™ CP40XX coatings adhere to various materials including, but not limited to, metals, ceramics, refractories, and quartz, and are resistant to outdoor weathering, UV light, salt spray, chemical corrosion, thermal cycling. While embodiments of heat resistant and/or flame retardant well tools and tool components in accordance with the present invention may be manufactured and used with any one or a combination of these particular coatings, it is intended that other embodiments may use any one or combination of any other heat resistant and/or flame retardant coatings.

[0024] In producing heat resistant and/or flame retardant well tools, a thermal coating may be applied to the surface of the well tools or tool components by brush, roller, spray or other application method.

[0025] An embodiment of the present invention includes heat resistant and/or flame retardant perforating tools. Figure 1 illustrates a conventional perforating system including a plurality of shaped charges 10, which may be conveyed downhole via a hollow carrier gun 30. Within the hollow

carrier 30, a loading tube 40 is positioned. The loading tube 40 includes a plurality of openings proximal, for receiving and mounting the shaped charges 10. Generally, a series of hollow carrier guns may be assembled to form a perforating gun string 50 having a desired length. An example length of each gun may be about 20 feet. To make a perforating gun string 50 of a few hundred feet or longer, several guns may be connected together in series by adapters 52. Each of the adapters 52 contains a ballistic transfer component, which may be in the form of donor and receptor booster explosives. Ballistic transfer takes place from one gun to another as the detonation wave jumps from the donor to the receptor booster. At the end of the receptor booster is a detonating cord that carries the wave and sets off the shaped charges in the next gun. Examples of explosives that may be used in the various explosive components (e.g., shaped charges 10, detonating cord 14, and boosters) include RDX, HMX, HNS, TATB, and others. Moreover, a propellant material in the form of a sleeve, strip, patch, or other configuration may be positioned in the path of the shaped charges 10 to enhance the perforations and to stimulate the surrounding formation.

[0026] Once assembled, the gun string 50 is positioned in a wellbore 60 that is lined with casing 62. A tubing or pipe 64 extends inside the casing 62 to provide a conduit for well fluids to wellhead equipment (not shown). A portion of the wellbore 60 is isolated by packers 66 set between the exterior of the tubing 64 and the interior of the casing 62. The perforating gun string 50 may be lowered through the tubing or pipe 64 on a carrier line 70 (e.g., wireline, slickline, or coiled tubing). Once positioned at a desired wellbore interval where the gun string 50 is fired to create perforations in the surrounding casing and formation. In the event that a propellant material is used, the firing of the perforating gun 50 ignites the propellant material thereby generating a pressurized gas from the burning of the propellant material. The gas penetrates the formation via the perforations and cleans the perforation tunnels by pushing out debris. The pressurized propellant gas may also stimulate the surrounding formation to facilitate production by fracturing the formation.

[0027] Figure 2A illustrates an embodiment of the present invention, which includes a coated non-capsule shaped charge 10. The shaped charge 10 has an outer case 12 that acts as a containment vessel designed to hold the detonation

force of the detonating explosion long enough for a perforating jet to form. Common materials for the outer case 12 include steel or some other metal. A main explosive charge 16 is contained inside the outer case 12 and is sandwiched between the inner wall of the outer case 12 and the outer surface of a liner 20. A primer column 14 is a sensitive area that provides the detonating link between the main explosive charge 16 and a detonating cord 15, which is attached to the rear of the shaped charge 10. The entire shaped charge is coated with a thermal coating 11 to protect the charge from exposure to high temperature and/or fire.

[0028] Alternatively, an embodiment of the present invention may also include a capsule charge having a thermal coating for protection from heat and/or flame. For example, as shown in Figure 2B, a linear strip 80 may include one or more capsule charges 82, each having a thermal coating 83. The capsule charges 82 may be mounted together via a retaining bracket 84 with a detonating cord 86 attached to the back of each capsule charge.

[0029] Figures 3A and 3B illustrate another embodiment of the present invention, which includes a coated perforating gun assembly. The perforating gun assembly includes a

plurality of shaped charges 10, which may be conveyed downhole via a hollow carrier gun 30. The shaped charges 10 may be non-capsule charges since the shaped charges are protected from the environment by the hollow carrier 30, which is typically sealed. The hollow carrier 30 may also include a plurality of recesses 32 formed in the outer wall. The recesses 32 are typically localized areas where the wall thickness of the carrier 30 is reduced to facilitate penetration by the shaped charges 10. Within the hollow carrier 30, a loading tube 40 is positioned. The loading tube 40 includes a plurality of openings 42 proximal, for receiving and mounting the shaped charges 10. The openings 42 of the loading tube 40 are typically aligned with the recesses 32 of the hollow carrier 30. The perforating gun assembly further includes thermal coatings 11, 34, and 44 covering one or more of the shaped charges 10, the carrier 30, and the loading tube 40 respectively. In another embodiment, end connectors 45 and adaptors 52 (Figure 1) for connecting multiple perforating gun assemblies to form a perforating string 50 are also coated with a thermal coating. Moreover, while the perforating gun assembly of Figure 3 includes a carrier 30, a loading tube 40, and one or more shaped charges 10, all of which have

a thermal coating, it is intended that other embodiments of the present invention include any combination of protected components including, but not limited to, coated shaped charges 10 only, a coated carrier 30 only, a coated loading tube 40 only, or other combinations of coated perforating tool components.

[0030] In embodiments of the present invention, the loading tube 40 may be fabricated from conventional metal materials (e.g., tubular steel, pipe, sheet metal, or equivalent materials) or non-metal materials (e.g., stamped and/or molded paper pulp, plastic, high-density polystyrene, or other equivalent materials). In these embodiments, the coating 44 is applied onto the metal or non-metal material.

[0031] In other embodiments, the heat resistant and/or flame retardant perforating assembly may include propellant material positioned outside the gun 50 or casing 62 (Figure 1) for cleaning debris from the perforating tunnels and stimulating the formation. In accordance with the present invention, the propellant material may be coated with a thermal coating to prevent an accidental ignition. In operation, when the perforating gun 50 is fired, the shock and heat generated from the detonated shaped charges 10

penetrate the coating around the propellant material and ignites the propellant material.

[0032] While some embodiments of the present invention have been described with respect to a heat resistant and/or flame retardant perforating gun, it is intended that other embodiments include other explosive well tools having a thermal coating including, but not limited to, an explosive tubing cutter. An example of an explosive tubing cutter is described in U.S. Patent Application Serial No. 10/017,116, published as US 2003/011120 A1, which is incorporated herein by reference. As with embodiments of the perforating gun described above, embodiments of the explosive tubing cutter may include a carrier or housing coated with a thermal coating, at least one shaped charge coated with a thermal coating, or both.

[0033] Another embodiment of the present invention includes heat resistant and/or flame retardant explosive components. For example, detonators, detonating cords, firing heads, initiators, charges, switches, processor units, power supplies, and other explosive components may be coated with a thermal coating to protect from damage or inadvertent ignition during manufacturing, shipping, packaging, assembly, and/or operation.

[0034] Figure 4 illustrates an embodiment of the present invention, which includes a heat resistant and/or flame retardant exploding foil initiator (EFI) 100. The EFI 100 is coated with a thermal coating 110.

[0035] Figure 5 illustrates another embodiment of the present invention, which includes a heat resistant and/or flame retardant detonator assembly 200 for detonating an explosive. In this particular embodiment, the detonator assembly 200 includes safety components to avoid accidental firing during rig-up or rig-down, and/or to disarm an attached perforating gun (or other ballistic assembly) if downhole conditions are unsafe for firing. Particularly, the detonator assembly 200 includes an EFI 100 in connection with a capacitor discharge unit (CDU) 210 fireset for firing the detonator 200; an initiator board 220 in connection with the CDU 210 for supplying the energy pulse to the CDU 210; a processor 230 in connection with the initiator board 220 for receiving and verifying the firing command; and a battery 240 in connection with the processor 230 for supplying power to initiate the detonator 200. The entire detonator assembly 200 is coated with a thermal coating 250. In other embodiments, the entire assembly is not coated, but rather only particular components or a

combination of components are coated with the thermal coating 250.

[0036] While the embodiment shown in Figure 5 includes a detonator having a safety system, it is intended that other embodiments of the present invention include a thermal coating applied to any conventional detonator or device containing a primary explosive material that is used to initiate an explosive sequence. For example, an embodiment of the present invention may include a heat resistant and/or flame retardant electrical detonator (or blasting cap) having a fuse material that burns when high voltage is applied to initiate the primary high explosive. As another example, an embodiment of the present invention may include may include a heat resistant and/or flame retardant percussion detonator containing abrasive grit and a primary high explosive in a sealed container that is activated by a firing pin. In this example, the impact force of the firing pin is sufficient to initiate the ballistic sequence that is then transmitted to the detonating cord. These and other downhole detonators may be protected from exposure to heat and flame (e.g., from an accidental fire) by application of a thermal coating.

[0037] Another embodiment of the present invention includes

heat resistant and/or flame retardant explosive actuators for actuating downhole tools and/or systems by igniting an explosive. For example, U.S. Patent No. 6,651,747, which is incorporated herein by reference, includes an anchoring device for use in a perforating operation to prevent movement of a perforating gun downhole. To actuate and set the anchor device, an electrical signal detonates a detonator release mechanism, which causes engagement mechanisms to engage the inner wall of the casing or tubing. In accordance with the present invention, the anchoring device and/or the detonator release mechanism may be coated with a heat resistant and/or flame resistant coating to prevent accidental detonation when exposed to heat or flame. Also, for example, U.S. Patent No. 6,102,120, which is incorporated herein by reference, includes a downhole zonal isolation tool having an epoxy sleeve for sealing against a casing. An embodiment of the isolation tool includes a local heat source (e.g., thermite or some other exothermic pyrotechnic energy source) contained in a housing, which when actuated cures the epoxy sleeve. In accordance with the present invention, the zonal isolation tool and/or the local heat source may be coated with a thermal coating to prevent accidental ig-

nition when exposed to heat or flame.

[0038] Yet another embodiment of the present invention includes heat resistant and/or flame retardant packaging, and shipping materials for safely transporting and storing heat and/or flame-sensitive well tools, explosives, and/or explosive components.

[0039] Figure 6 illustrates an embodiment of the present invention, which includes a container 300 (e.g., a box, crate, bag, or other container) having a thermal coating 310 for holding and protecting one or more shaped charges 10 during shipping or storage. In operation, a container 300 is provided to hold the shaped charges 10 -- or other downhole tools. The container 300 is coated with a thermal coating 310, and the shaped charges 10 are placed inside the container for shipping and/or storing.

[0040] Still with respect to Figure 6, another embodiment of the present invention includes packing material 400 (e.g., styrofoam, plastic, paper, paperboard or other packing material) having a thermal coating 410 for holding and protecting one or more shaped charges 10 in a container 300 during shipping or storage. In another embodiment, both the packing material 400 and the container 300 are coated with a thermal coating 310, 410 respectively. In

operation, a container 300 and packing materials 400 are provided to hold and secure the shaped charges 10 -- or other downhole tools. The packing materials 400 are coated with a thermal coating 410, and the shaped charges 10 are secured within the container 300 by the packing material 400 for shipping and/or storing.

[0041] While this embodiment includes a container 300 and packing materials 400 for holding one or more shaped charges 10, it is intended that other embodiments of the present invention include containers and/or packing materials coated with a thermal coating for carrying any heat and/or flame-sensitive well tools, explosives, and/or explosive components including, but not limited to, perforating guns, carriers, loading tubes, gun adapters, tubing cutters, detonators, detonating cords, firing heads, initiators, charges, propellants, explosive actuators, switches, processor units, power supplies, RDX, HMX, HNS, and/or TATB explosives, and so forth.

[0042] Although only a few exemplary embodiments of this invention have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advan-

tages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention.